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(54) **GAS TURBINE ENGINE BLADE CONTAINMENT ASSEMBLY**

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(52) **U.S. Cl.** **415/9**; 415/173.4
(58) **Field of Search** 415/200, 220, 415/219.1, 173.4, 174.4, 9; 60/223, 30.091

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(57) **ABSTRACT**

A gas turbine engine rotor blade containment assembly comprises a generally cylindrical, or frustoconical, stiff containment casing **(54)**, a generally cylindrical, or frustoconical, flexible structure **(62)** arranged within and spaced radially from the stiff containment casing **(54)** by crushable structures **(64, 66)** at axially spaced positions on the flexible structure **(62)**. A viscoelastic material **(68)** is arranged to fill the space **(70)** between the stiff containment casing **(54)**, the flexible structure **(62)** and the crushable structures **(64, 66)**. The viscoelastic material **(68)** provides local stiffening of the blade containment assembly in the region of a fan blade **(34)** impact and provides energy dissipation by viscoelastic damping of the flexing of the flexible structure **(62)** and plastic deformation in the crushing of the crushable structures **(64, 66)**.

21 Claims, 2 Drawing Sheets

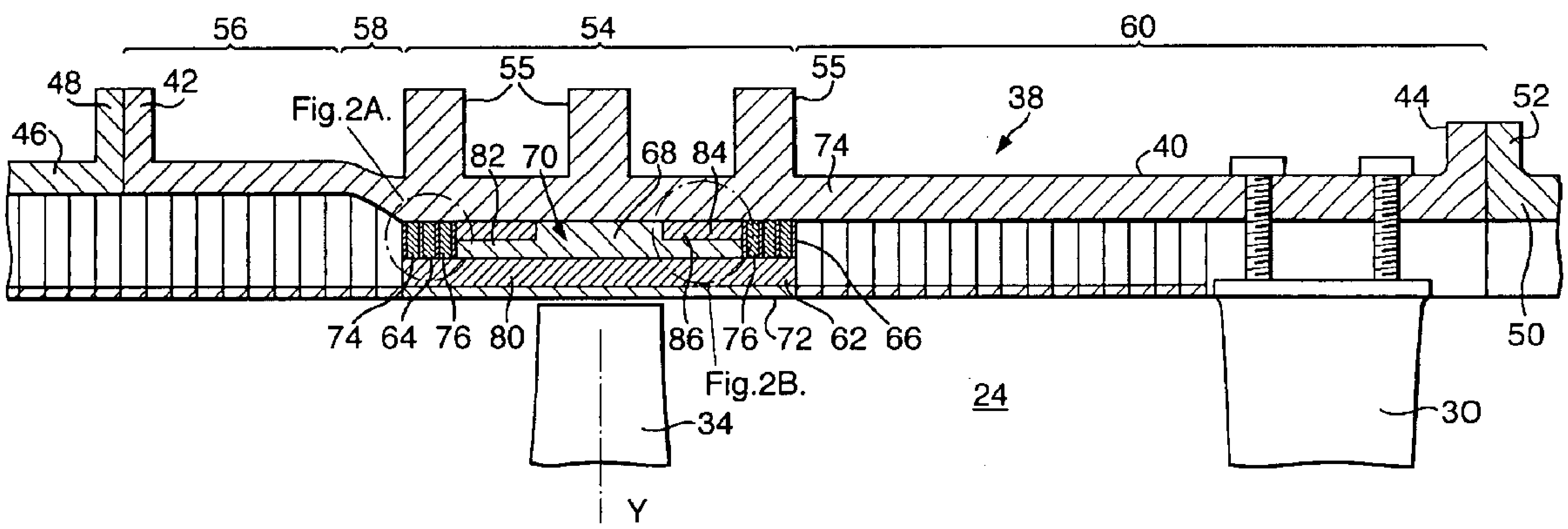


Fig.1.

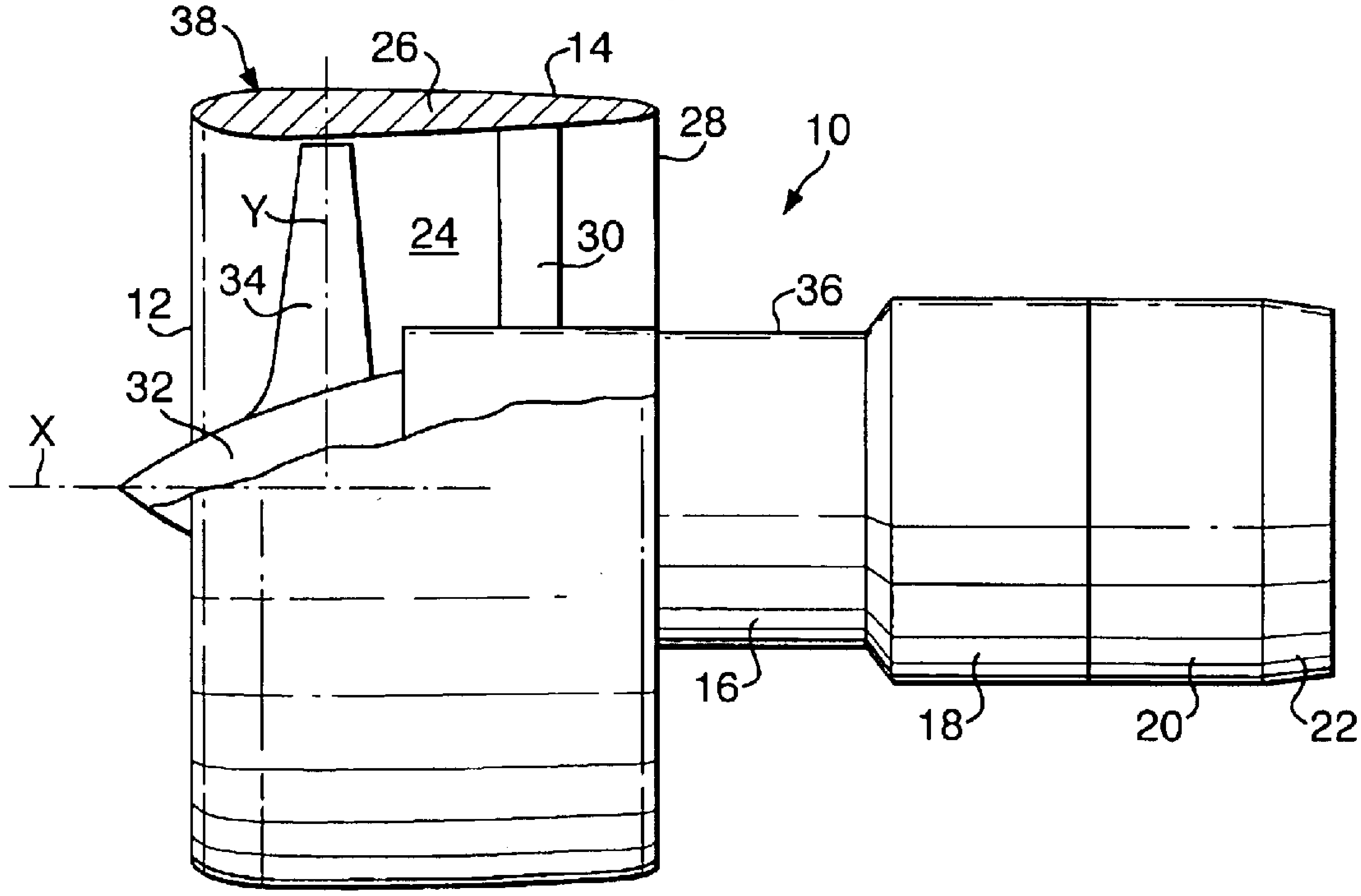
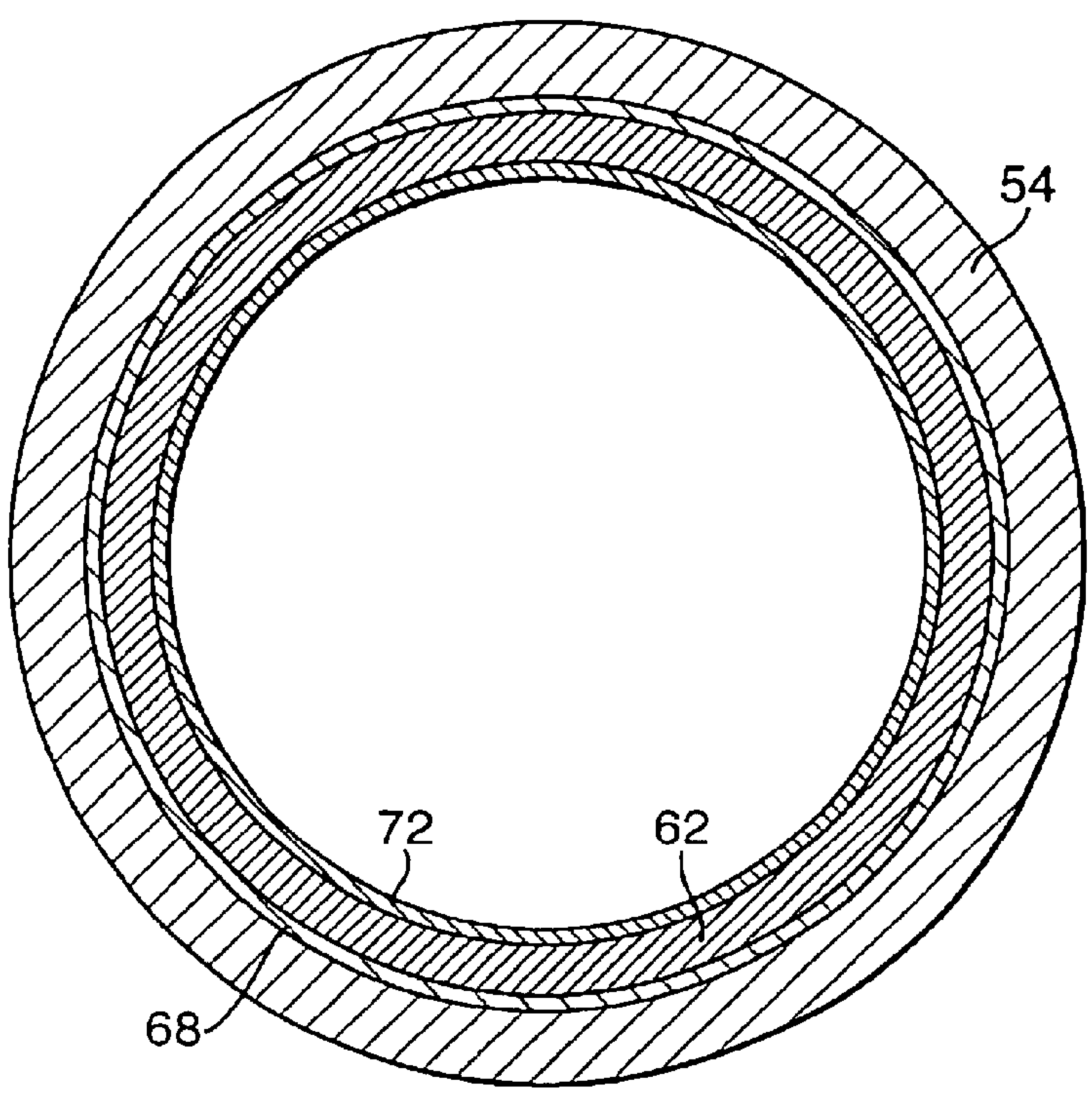


Fig.3.



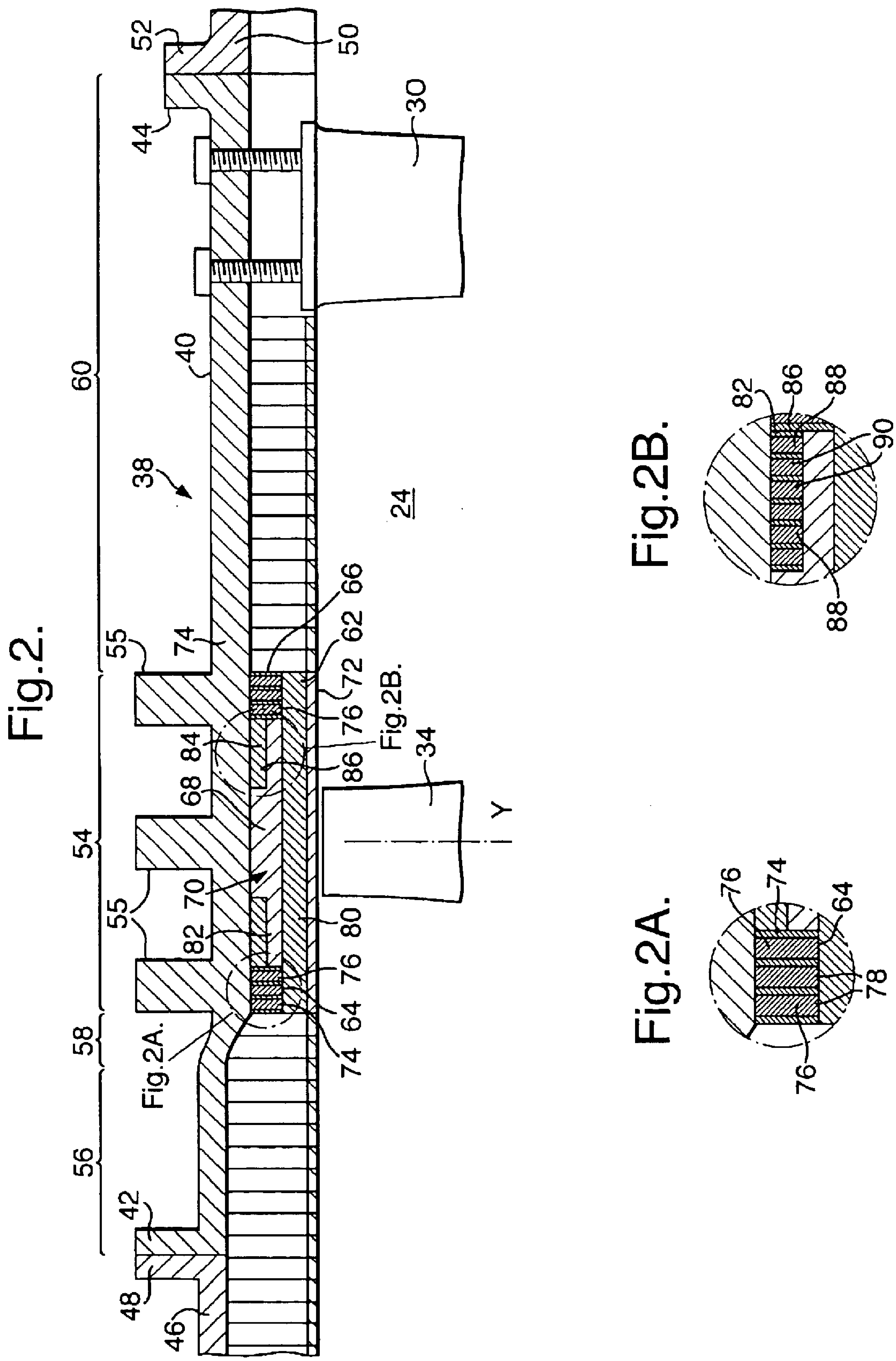


Fig.2.

Fig.2A.

Fig.2B.

GAS TURBINE ENGINE BLADE CONTAINMENT ASSEMBLY

The present invention relates to gas turbine engine casings, particularly gas turbine engine fan casings, more particularly to an improved blade containment assembly for use within or forming part of the gas turbine engine casing.

Turbofan gas turbine engines for powering aircraft conventionally comprise a core engine, which drives a fan. The fan comprises a number of radially extending fan blades mounted on a fan rotor, which is enclosed by a generally cylindrical, or frustoconical, fan casing. The core engine comprises one or more turbines, each one of which comprises a number of radially extending turbine blades enclosed by a cylindrical, or frustoconical, casing.

There is a remote possibility that with such engines that part, or all, of a fan blade, or a turbine blade, could become detached from the remainder of the fan or turbine. In the case of a fan blade becoming detached this may occur as the result of, for example, the turbofan gas turbine engine ingesting a bird or other foreign object.

The use of containment rings for turbofan gas turbine engine casings is well known. It is known to provide generally cylindrical, or frustoconical, relatively thick metallic containment rings. It is also known to provide circumferentially and radially extending ribs on metallic containment rings. It is also known generally cylindrical, or frustoconical, locally thickened, isogrid, metallic containment rings. Furthermore it is known to provide strong fibrous material wound around relatively thin metallic casings or around the above-mentioned containment casings. In the event that a blade becomes detached it passes through the casing and is contained by the fibrous material.

Our published European patent application EP1245791A2 discloses the use of an upstream containment portion comprising circumferentially and radially extending ribs on a metallic containment ring and a downstream portion comprising a stiff and lightweight honeycomb material on the inner surface of a containment ring. The upstream portion is arranged in the plane of the fan blades to arrest the fan blade tip through plastic deformation and the downstream portion is arranged to arrest the fan blade root through crushing of the honeycomb material.

However, this containment assembly is too heavy, when used for large diameter turbofan gas turbine engines even if the upstream portion of the containment ring comprises steel and the downstream portion of the containment ring comprises titanium.

Accordingly the present invention seeks to provide a novel gas turbine engine rotor blade containment assembly, which reduces, preferably overcomes, the above-mentioned problems.

Accordingly the present invention provides a gas turbine engine rotor blade containment assembly comprises a generally cylindrical, or frustoconical, stiff containment casing, a generally cylindrical, or frustoconical, flexible structure arranged within and spaced radially from the stiff containment casing by crushable structures at axially spaced positions on the flexible structure, a viscoelastic material arranged to at least partially fill the space between the stiff containment casing, the flexible structure and the crushable structures.

Preferably the viscoelastic material is arranged to fill the space between the stiff containment casing, the flexible structure and the crushable structures.

Preferably the stiff containment casing comprises circumferentially extending ribs extending radially outwardly from the casing to stiffen the casing.

Alternatively the stiff containment casing comprises a cellular structure to stiffen the casing.

Preferably the crushable structure comprises a cellular structure or metal foam. The crushable structure may contain a viscoelastic material in the pores of the cellular structure or metal foam. Preferably the pores of the cellular structure or metal foam are interconnected with the space between the stiff containment casing, the flexible structure and the crushable structures.

Preferably the flexible structure comprises a cellular structure or metal foam. The cellular structure may comprise honeycomb.

Preferably squeeze film lands are arranged in the space between the stiff casing and the flexible structure. Preferably the squeeze film lands are arranged axially adjacent to the crushable structures. Preferably the squeeze film lands are arranged adjacent to the stiff containment casing and spaced radially from the flexible structure. Preferably the squeeze film lands comprise a crushable material. Preferably the crushable material comprises a cellular structure or metal foam.

Preferably the crushable material comprises a viscoelastic material in the pores of the cellular structure or metal foam. Preferably the pores of the cellular structure or metal foam are interconnected with the space between the stiff containment casing, the flexible structure and the crushable structures.

The viscoelastic material may comprise particles.

Preferably an abradable layer is arranged on the radially inner surface of the flexible structure.

Preferably the stiff containment casing comprises a steel alloy, aluminium, an aluminium alloy, magnesium, a magnesium alloy, titanium, a titanium alloy, nickel or a nickel alloy.

The viscoelastic material may comprise grease, a thixotropic paste, a polymer resin or a granular material.

The stiff containment casing may be a fan containment casing, a compressor containment casing or a turbine containment casing.

The present invention will be more fully described by way of example with reference to the accompanying drawings in which:

FIG. **1** shows a turbofan gas turbine engine having a rotor blade containment assembly according to the present invention.

FIG. **2** is an enlarged cross-sectional view of the rotor blade containment assembly shown in FIG. **1**.

FIG. **2**A is an enlargement of a crushable structure shown in FIG. **2**.

FIG. **2**B is an enlargement of a squeeze film land shown in FIG. **2**.

FIG. **3** is a reduced cross-sectional view in the direction of arrows A in FIG. **2**.

A turbofan gas turbine engine **10**, as shown in FIG. **1**, comprises in axial flow series an intake **12**, a fan section **14**, a compressor section **16**, a combustion section **18**, a turbine section **20** and an exhaust **22**. The turbine section **20** comprises one or more turbines arranged to drive one or more compressors in the compressor section **16** via shafts (not shown). The turbine section **20** also comprises a turbine to drive the fan section **14** via a shaft (not shown). The fan section **14** comprises a fan duct **24** defined partially by a fan casing **26**. The fan duct **24** has an outlet **28** at its axially downstream end. The fan casing **26** is secured to the core engine casing **36** by a plurality of radially extending fan outlet guide vanes **30**. The fan casing **26** surrounds a fan rotor **32**, which carries a plurality of circumferentially spaced radially extending fan blades **34**. The fan rotor **32** and fan blades **34** rotate about the axis X of the gas turbine engine **10**, substantially in a plane Y perpendicular to the axis X. The fan casing **26** also comprises a fan blade containment assembly **38**, which is arranged substantially in the plane Y of the fan blades **34**.

The fan casing **26** and fan blade containment assembly **38** is shown more clearly in FIGS. **2** and **3**. The fan blade containment assembly **38** comprises a generally cylindrical, or frustoconical, metal casing **40**. The metal casing **40** comprises an upstream flange **42** by which the fan blade containment assembly **38** is connected to a flange **48** on an intake assembly **46** of the fan casing **26**. The metal casing **40** also comprises a downstream flange **44** by which the fan blade containment assembly **38** is connected to a flange **52** on a rear portion **50** of the fan casing **26**.

The metal casing **40** provides the basic fan blade containment and provides a connection between the intake casing **46** and the rear casing **50**.

The metal casing **40** comprises an upstream portion **56**, a transition portion **58**, a main blade containment portion **54** and a downstream portion **60**. The upstream portion **56** comprises the flange **42** and the downstream portion **60** comprises the flange **44**.

The upstream portion **56** is upstream of the plane Y of the fan blades **34** and provides debris protection for the fan blade containment assembly **38**. The main blade containment portion **54** is substantially in the plane Y containing the fan blades **34** and comprises one or more integral ribs **55**, which extend radially outwardly from the main blade containment portion **54**. The ribs **55** may be T-shaped in cross-section or other suitable shapes. The ribs **55** extend circumferentially around the main blade containment portion **54** to stiffen the main blade containment portion **54** to improve the fan blade containment properties. The transition portion **58** connects the main blade containment portion **54** and the upstream containment portion **56** to transmit loads from the main blade containment portion **54** to the upstream flange **42** on the upstream portion **56**. The downstream portion **60** is provided downstream of the plane Y of the fan blades **34**, and provides protection for where a root of a fan blade **34** impacts the fan blade containment assembly **38**.

The main blade containment portion **54** comprises a generally cylindrical, or frustoconical, stiff containment casing. A generally cylindrical, or frustoconical, flexible structure **62** is arranged within and spaced radially from the stiff containment casing **54** by crushable structures **64** and **66** at axially spaced positions, in particular the axial ends, on the flexible structure **62**. A viscoelastic material **68** is arranged to fill the space **70** between the stiff containment casing **54**, the flexible structure **62** and the crushable structures **64** and **66**. An abradable layer **72** is arranged on the radially inner surface of the flexible structure **62**. The abradable layer **72** provides a close clearance with the tips of the fan blades **34** in normal operation. The abradable layer **72** comprises a low-density metal foam, or any suitable filler material well known to those skilled in the art.

The crushable structures **64** and **66** comprise a cellular structure **74** or metal foam. The crushable structures **64** and **66** contain a viscoelastic material **76** in the pores **78** of the cellular structure **74** or metal foam, as shown more clearly in FIG. **2**A. The pores **78** of the cellular structure **74** or metal foam are interconnected with the space **70** between the stiff containment casing **54**, the flexible structure **62** and the crushable structures **64** and **66**.

The flexible structure **62** comprises a cellular structure **80** or metal foam. The cellular structure **80** comprises honeycomb.

Squeeze film lands **82** and **84** are arranged in the space **70** between the stiff containment casing **54** and the flexible structure **62**. The squeeze film lands **82** and **84** are arranged axially adjacent to the crushable structures **64** and **66**. The squeeze film lands **82** and **84** are arranged radially adjacent to the stiff containment casing **54** and spaced radially from the flexible structure **62**. The squeeze film lands **82** and **84** comprise a crushable material **86**. The crushable material **86** comprises a cellular structure or metal foam.

The crushable material **86** comprises a viscoelastic material **90** in the pores **88** of the cellular structure or metal foam, as shown more clearly in FIG. **2**B. The pores of the cellular structure or metal foam are interconnected with the space **70** between the stiff containment casing **54**, the flexible structure **62** and the crushable structures **64** and **66**.

The viscoelastic material may comprise solid particles, hollow particles or a high viscosity liquid. The hollow particles may be crushable to allow the viscoelastic material to be crushed.

In operation of the turbofan gas turbine engine **10**, in the event that a fan blade **34** or radially outer portion of a fan blade **34** becomes detached it encounters the main containment portion **54** of the fan blade containment assembly **38**. The fan blade **34**, or radially outer portion of the fan blade **34,** firstly encounters the flexible structure **62**. The impact of the fan blade **34** produces flexural vibrations in the flexible structure **62** and causes the space **70** between the flexible structure **62** and the stiff containment casing **54** to be reduced locally by crushing of the crushable structures **64** and **66** locally to the point of impact of the fan blade **34**. The localised reduction of the space **70** between the flexible structure **62** and the stiff containment casing **54** firstly provides a closing effect for a squeeze film between the squeeze film lands **82** and **84** and the flexible structure **62** and secondly provides an additional pressure to the viscoelastic material **68**, which acts as a fluid under the shock loading of the fan blade **34** impact. At the point of impact of the fan blade **34** the viscoelastic material **68** becomes stiffer, in response to the increase in pressure on the viscoelastic material **68** by the crushing of the crushable structures **64** and **66** which reduces the space **70** between the flexible structure **62** and the stiff containment casing **54**, and produces a squeeze film effect between the squeeze film lands **82** and **84** and the flexible structure **62**. The viscoelastic material **68** damps the flexural vibrations of the flexible structure **62** at positions away from the point of impact of the fan blade **34**, which would expand and contract the space **70** between the flexible structure **62** and the stiff containment casing **54**. The relative movement of the particles in the viscoelastic material **68** also contributes to the damping effect by the impacts between particles damping vibrations and noise.

Additionally the viscoelastic material **76** in the pores **78** of the crushable structures **64** and **66** is squeezed out of the crushable structures **64** and **66** into the space **70** to further increase the pressure in the viscoelastic material **68**. Also the viscoelastic material in the pores of the squeeze film lands **82** and **84** is squeezed out of the squeeze film lands **82** and **84** into the space **70** to further increase the pressure in the viscoelastic material **68**. The movement of the viscoelastic material out of the pores of the crushable structures **64** and **66** and the squeeze film lands **82** and **84** provides additional damping.

The present invention provides a reduction in weight of the fan blade containment assembly because the viscoelastic material **68** provides local stiffening of the fan blade containment assembly in the region of a fan blade **34** impact and provides energy dissipation by viscoelastic damping of the flexing of the flexible structure **62**, impact damping by impacts between particles in the viscoelastic material **68** and plastic deformation in the crushing of the crushable structures **64** and **66**.

In a further embodiment, similar to that shown in FIG. **2**, the squeeze film lands **82** and **84** are solid or are crushable and do not contain a viscoelastic material. The crushable structures **64** and **66** do not contain a viscoelastic material.

The flexible structure **62** may be used for passive noise reduction if the flexible structure comprises for example a honeycomb.

Alternatively the stiff containment casing comprises a cellular structure, a honeycomb structure, to stiffen the casing.

The viscoelastic material may be any suitable material that has viscoelastic properties at the impact conditions. The viscoelastic material is capable of crushing at the point of impact and is capable of damping of vibrations away from the point of impact. The viscoelastic material may comprise grease, a thixotropic paste, a polymer resin, an elastomeric material, for example rubber or synthetic rubber, or a granular material.

Preferably the stiff containment casing comprises a steel alloy, aluminium, an aluminium alloy, magnesium, a magnesium alloy, titanium, a titanium alloy, nickel, a nickel alloy, a composite, a metal matrix composite, a metal/ceramic mix or other suitable materials.

The stiff containment casing may be a fan containment casing, a compressor containment casing or a turbine containment casing.

Although the present invention has been described with reference to squeeze film lands between the stiff containment casing and the flexible structure it may be possible to dispense with them and to adjust the distance of the space between the stiff containment casing and the flexible structure to achieve a similar effect.

The flexible structure **62** may also be crushable locally to the point of impact of the fan blade **34** if the flexible structure **62** comprises a cellular structure. In that instance the flexible structure **62** is flexible up to a predetermined load and is crushable above the predetermined load.

We claim:

1. A gas turbine engine rotor blade containment assembly comprises a generally cylindrical, or frustoconical, stiff rotor blade containment casing, a generally cylindrical, or frustoconical, flexible structure arranged within and spaced radially from the stiff containment casing by crushable structures at axially spaced positions on the flexible structure, a viscoelastic material arranged to at least partially fill the space between the stiff containment casing, the flexible structure and the crushable structures.

2. A gas turbine engine rotor blade containment assembly as claimed in claim **1** wherein the viscoelastic material is arranged to fill the space between the stiff containment casing, the flexible structure and the crushable structures.

3. A gas turbine engine rotor blade containment assembly as claimed in claim **1** wherein the stiff containment casing comprises circumferentially extending ribs extending radially outwardly from the casing to stiffen the casing.

4. A gas turbine engine rotor blade containment assembly as claimed in claim **1** wherein the stiff containment casing comprises a cellular structure to stiffen the casing.

5. A gas turbine engine rotor blade containment assembly as claimed in claim **4** wherein the cellular structure comprises honeycomb.

6. A gas turbine engine rotor blade containment assembly as claimed in claim **1** wherein the crushable structures comprise a cellular structure or metal foam.

7. A gas turbine engine rotor blade containment assembly as claimed in claim **6** wherein the crushable structures contain a viscoelastic material in the pores of the cellular structure or metal foam.

8. A gas turbine engine rotor blade containment assembly as claimed in claim **7** wherein the viscoelastic material contains particles.

9. A gas turbine engine rotor blade containment assembly as claimed in claim **1** wherein the flexible structure comprises a cellular structure or metal foam.

10. A gas turbine engine rotor blade containment assembly as claimed in claim **1** wherein squeeze film lands are arranged in the space between the stiff casing and the flexible structure.

11. A gas turbine engine rotor blade containment assembly as claimed in claim **10** wherein the squeeze film lands are arranged axially adjacent to the crushable structures.

12. A gas turbine engine rotor blade containment structure as claimed in claim **10** wherein the squeeze film lands are arranged adjacent to the stiff containment casing and spaced radially from the flexible structure.

13. A gas turbine engine rotor blade containment assembly as claimed in claim **10** wherein the squeeze film lands comprise a crushable material.

14. A gas turbine engine rotor blade containment assembly as claimed in claim **13** wherein the crushable material comprises a cellular structure or metal foam.

15. A gas turbine engine rotor blade containment assembly as claimed in claim **14** wherein the crushable material comprises a viscoelastic material in the pores of the cellular structure or metal foam.

16. A gas turbine engine rotor blade containment assembly as claimed in claim **15** wherein the pores of the cellular structure or metal foam are interconnected with the space between the stiff containment casing, the flexible structure and the crushable structures.

17. A gas turbine engine rotor blade containment assembly as claimed in claim **1** wherein the viscoelastic material comprises particles.

18. A gas turbine engine rotor blade containment assembly as claimed in claim **1** wherein an abradable layer is arranged on the radially inner surface of the flexible structure.

19. A gas turbine engine rotor blade containment assembly as claimed in claim **1** wherein the stiff containment casing comprises a steel alloy, aluminium, an aluminium alloy, magnesium, a magnesium alloy, titanium, a titanium alloy, nickel, a nickel alloy, a composite, a metal matrix composite or a metal/ceramic mix.

20. A gas turbine engine rotor blade containment assembly as claimed in claim **1** wherein the stiff containment casing is a fan containment casing, a compressor containment casing or a turbine containment casing.

21. A gas turbine engine rotor blade containment assembly as claimed in claim **1** wherein the viscoelastic material comprises grease, a thixotropic paste, a polymer resin or a granular material.

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